

What is claimed is:

1. A magnetoresistive sensor comprising a stack of layers and capable of sensing external magnetic fields when a sense current is applied perpendicular to the planes of the layers in the stack, the stack of layers including:

a first nonmagnetic spacer layer;

a second nonmagnetic spacer layer;

a free ferromagnetic layer between the first and second spacer layers and having a magnetization direction oriented substantially longitudinally along the length of the layer in the absence of an external magnetic field, said free layer magnetization direction being substantially free to rotate in the presence of an external magnetic field in the range of interest;

a pinned ferromagnetic layer adjacent the first spacer layer and having a magnetization direction oriented in a preferred direction;

a first antiferromagnetic layer exchange coupled to the pinned layer and preventing substantial rotation of the magnetization of the pinned layer in the presence of an external magnetic field in the range of interest;

a ferromagnetic stabilizing layer adjacent the second spacer layer; and

a second antiferromagnetic layer exchange coupled to the stabilizing layer, the second antiferromagnetic layer having a blocking temperature less than the blocking temperature of the first antiferromagnetic layer, the stabilizing layer and the free layer having nonlongitudinally-oriented magnetic domains magnetically-coupled across the second spacer layer in the absence of an external magnetic field and the absence of a sense current.

2. The sensor according to claim 1 wherein the stabilizing layer and the free layer are ferromagnetically coupled across the second spacer layer.

3. The sensor according to claim 1 wherein the nonlongitudinally-oriented magnetically-coupled magnetic domains of the stabilizing layer and the free layer are oriented generally as a vortex magnetization pattern within the free layer.

4. The sensor according to claim 1 wherein the free layer has substantially fewer nonlongitudinally-oriented magnetic domains in the presence of a sense current.

5. The sensor according to claim 1 wherein the first nonmagnetic spacer layer is electrically conducting.

6. The sensor according to claim 1 wherein the sensor is a magnetic tunnel junction and wherein the first nonmagnetic spacer layer is electrically insulating.

7. The sensor according to claim 1 wherein the second spacer layer is formed of a material selected from the group consisting of ruthenium (Ru), chromium (Cr), rhodium (Rh), iridium (Ir), copper (Cu), vanadium (V), niobium (Nb) and their alloys.

8. The sensor according to claim 1 wherein each of the first and second antiferromagnetic layers is formed of a material selected from the group consisting of FeMn, PtMn, NiMn, PdPtMn, RhMn, CrPtMn, FeRhMn and IrMn.

9. The sensor according to claim 8 wherein each of the first and second antiferromagnetic layers is formed of substantially the same material, the thickness of the second antiferromagnetic layer being less than the thickness of the first antiferromagnetic layer.

10. The sensor according to claim 1 further comprising a ferromagnetic biasing layer outside the stack near each side edge of the free layer for longitudinally biasing the magnetization direction of the free layer along its length.

11. A current-perpendicular-to-the-plane spin-valve magnetoresistive read head for sensing data recorded on a magnetic recording medium when a sense current is applied to the head, the head comprising:

- a substrate;

- a first antiferromagnetic layer on the substrate:

- a pinned ferromagnetic layer exchange coupled to the first antiferromagnetic layer and having a magnetization direction oriented substantially perpendicular to the plane of the recording medium and substantially prevented from rotating in the presence of magnetic fields from the recording medium;

- a first electrically-conducting nonmagnetic spacer layer on the pinned layer;

- a free ferromagnetic layer on the first nonmagnetic spacer layer and having a magnetization direction oriented substantially parallel to the plane of the recording medium in the absence of an external magnetic field, said free layer magnetization direction being substantially free to rotate in the presence of magnetic fields from the recording medium;

- a second nonmagnetic spacer layer on the free layer;

- a ferromagnetic stabilizing layer on the second spacer layer, the stabilizing layer and the free layer having nonlongitudinally-oriented magnetic domains ferromagnetically coupled across the second spacer layer in the absence of an external magnetic field and the absence of a sense current; and

- a second antiferromagnetic layer on and exchange coupled to the stabilizing layer and substantially fixing the orientation of the nonlongitudinally-oriented magnetic domains in the stabilizing layer in the absence of an external magnetic field and the absence of a sense

current, the second antiferromagnetic layer having a blocking temperature less than the blocking temperature of the first antiferromagnetic layer.

12. The head according to claim 11 wherein the nonlongitudinally-oriented magnetically-coupled magnetic domains of the stabilizing layer and the free layer are oriented generally as a vortex magnetization pattern within the free layer.

13. The head according to claim 11 wherein the free layer has substantially fewer nonlongitudinally-oriented magnetic domains in the presence of a sense current.

14. The head according to claim 11 wherein the second spacer layer is formed of a material selected from the group consisting of ruthenium (Ru), chromium (Cr), rhodium (Rh), iridium (Ir), copper (Cu), vanadium (V), niobium (Nb) and their alloys.

15. The head according to claim 11 wherein each of the first and second antiferromagnetic layers is formed of a material selected from the group consisting of FeMn, PtMn, NiMn, PdPtMn, RhMn, CrPtMn, FeRhMn or IrMn.

16. The head according to claim 15 wherein each of the first and second antiferromagnetic layers is formed of substantially the same material, the thickness of the second antiferromagnetic layer being less than the thickness of the first antiferromagnetic layer.

17. A method for making a current-perpendicular-to-the-plane magnetoresistive sensor comprising:

depositing on a substrate a first layer of antiferromagnetic material, a first layer of ferromagnetic material in contact with the first layer of antiferromagnetic material, a first spacer layer of nonmagnetic material in contact with the first layer of ferromagnetic material, a second layer of ferromagnetic material in contact with the first spacer layer, a second spacer layer of nonmagnetic material in contact with the second layer of ferromagnetic material, a third layer of ferromagnetic material in contact with the second spacer layer, and a second layer of antiferromagnetic material in contact with the third layer of ferromagnetic material and having a blocking temperature T_{BL} less than the blocking temperature T_{BH} of the first antiferromagnetic material;

setting the magnetization direction of the first layer of ferromagnetic material in a first direction, said magnetization of the first layer of ferromagnetic material being pinned by exchange coupling with the first layer of antiferromagnetic material;

applying a setting current in a direction substantially perpendicular to all of said layers in the presence of a temperature above T_{BL} but below T_{BH} to generate a vortex magnetic field in the third ferromagnetic layer; and

reducing the temperature to below T_{BL} while the setting current is applied to cause the magnetization generated in the third ferromagnetic layer by said vortex magnetic field to be fixed by exchange coupling with the second layer of antiferromagnetic material.